

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re reissue application of:)
U. S. Patent No: 6,031,294)
Issued: February 29, 2000) Application for Broadening
Inventor(s): Everett R. Geis,) Reissue
 Brian W. Peticolas,)
 Joel B. Wacknov)
For: Turbogenerator/Motor)
 Controller With Ancillary)
 Energy Storage/Discharge)

PRELIMINARY AMENDMENT

Box Reissue
Commissioner for Patents
Washington, D.C. 20231

Sir:

Please enter the following preliminary amendment in the above referenced application for a broadening reissue of U.S. Patent No. 6,031,294 being filed concurrently herewith. A check in the amount of \$864.00 for the extra claims fee pursuant to 37 C.F.R. 1.16 is enclosed herewith.

In the Specification:

Please delete all four paragraphs under the heading SUMMARY OF THE INVENTION starting at column 2, line 34 through column 3, line 13, and insert the following new text under the heading SUMMARY OF THE INVENTION:

In one aspect of the present invention, a method of controlling a permanent magnet turbogenerator/motor

is provided comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a pulse width modulated inverter to start the permanent magnet turbogenerator/motor to achieve self-sustaining operation of the permanent magnet turbogenerator/motor; disconnecting the utility electrical power from the pulse width modulated inverter once self sustaining operation of the permanent magnet turbogenerator/motor is achieved; reconfiguring the pulse width modulated inverter to supply voltage from the permanent magnet turbogenerator/motor; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In another aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self-sustaining operation of the gas turbine engine; disconnecting the utility electrical power from the pulse width modulated inverter once self-sustaining operation of the gas turbine engine is achieved; reconnecting the pulse width modulated inverter to the permanent magnet turbogenerator/motor through a rectifier bridge to reconfigure the pulse width modulated inverter to supply utility frequency voltage; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet

turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In a further aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine, comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a first contactor and a pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor through a second contactor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of the gas turbine engine; opening the first and second contactors to disconnect the utility electrical power from the pulse width modulated inverter once self-sustaining operation of the gas turbine engine is achieved; reconnecting the pulse width modulated inverter to the permanent magnet turbogenerator/motor through a rectifier bridge to reconfigure the pulse width modulated inverter to supply utility frequency voltage; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the inverter cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In still another aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine, comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a first contactor and

a multiple solid state switching device channel pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor through a second contactor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self-sustaining operation of the gas turbine engine; opening the first and second contactors to disconnect the utility electrical power from the multiple solid state switching device channel pulse width modulated inverter once self sustaining operation of the gas turbine engine is achieved; reconnecting the multiple solid state switching device channel pulse width modulated inverter to the permanent magnet turbogenerator/motor through a high frequency rectifier bridge to reconfigure the multiple solid state switching device channel pulse width modulated inverter; connecting the reconfigured multiple solid state switching device channel pulse width modulated inverter to utility power by closing a third contactor; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the gas turbine engine cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In yet another aspect, the invention provides a controller for a permanent magnet turbogenerator/motor including a gas turbine engine comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor; means to provide utility electrical power to said permanent magnet turbogenerator/motor through said pulse width modulated inverter to start said permanent magnet turbogenerator/motor to achieve self sustaining operation of the permanent magnet

turbogenerator/motor; means to disconnect the utility electrical power from said pulse width modulated inverter once self sustaining operation of said permanent magnet turbogenerator/motor is achieved; means to reconfigure said pulse width modulated inverter to supply voltage from said permanent magnet turbogenerator/motor; and an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the inverter cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In a further aspect, the invention provides a controller for a permanent magnet turbogenerator/motor having a gas turbine engine comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor; means to provide utility electrical power to said permanent magnet turbogenerator/motor through said pulse width modulated inverter to drive said permanent magnet turbogenerator/motor as a motor to accelerate said gas turbine engine of said permanent magnet turbogenerator/motor; means to provide spark and fuel to said gas turbine engine of said permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of said gas turbine engine; means to disconnect the utility electrical power from said pulse width modulated inverter and said permanent magnet turbogenerator/motor once self-sustaining operation of said gas turbine engine is achieved; a rectifier bridge operably associated with said pulse width modulated inverter and said permanent magnet turbogenerator/motor; means to reconnect said pulse width modulated inverter to said permanent magnet turbogenerator/motor through said rectifier bridge to reconfigure said pulse width modulated inverter to supply utility frequency voltage; and an energy storage and discharge system for the pulse width

modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the gas turbine engine cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In a still further aspect, the invention provides a controller for a permanent magnet turbogenerator/motor having a gas turbine engine and a permanent magnet generator/motor comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor, said pulse width modulated inverter having a plurality of solid state switching device channels; a first contactor operably associated with said pulse width modulated inverter; a second contactor operable associated with said the permanent magnet turbogenerator/motor; means to provide utility electrical power to said pulse width modulated inverter through said first contactor when closed to drive said permanent magnet turbogenerator/motor as a motor through said second contactor when closed to accelerate said gas turbine engine of said permanent magnet turbogenerator/motor; means to provide spark and fuel to said gas turbine engine of said permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of said gas turbine engine; means to open said first and second contactors to disconnect the utility electrical power from said pulse width modulated inverter once self sustaining operation of said gas turbine engine is achieved; a rectifier bridge operable associated with said pulse width modulated inverter and said permanent magnet turbogenerator/motor; a third contactor operably associated with said pulse width modulated inverter; means to reconnect said pulse width modulated inverter to said permanent magnet turbogenerator/motor through said rectifier bridge to reconfigure said pulse width modulated inverter; means to connect said reconfigured pulse width modulated inverter to supply utility frequency voltage to a load through said third contactor when closed; and an energy storage and discharge system for the pulse width modulated inverter to provide

electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In still another aspect, the invention provides a method of controlling a turbogenerator having an energy storage device, the method comprising rotating the turbogenerator at a first predetermined speed to provide a required amount of power to a load; in response to an increase in the amount of power required by the load, providing power to the load from the energy storage device; and then rotating the turbogenerator at a second predetermined speed to provide to the load the increased amount of power required.

POLYGRAPHIC GROUP
Please amend the BRIEF DESCRIPTION OF THE DRAWINGS starting at column 3, line 19 as follows:

FIG. 1 is a perspective view, partially cut away, of a permanent magnet turbogenerator/motor utilizing [the] a controller with an energy storage and discharge system [of] according to the present invention;

FIG. 2 is a functional block diagram of [the] an interface between the permanent magnet turbogenerator/motor of FIG. 1 and [the] a controller with an energy storage and discharge system [of] according to the present invention; and

FIG. 3 is a functional block diagram of [the] a permanent magnet turbogenerator/motor controller with an energy storage and discharge system [of] according to the present invention.

Please insert the following four paragraphs immediately after the heading DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS starting at column 3, line 34:

The turbogenerator/motor controller of the present invention is a microprocessor-based inverter having multiple modes of operation and including an energy storage and discharge system. To start the turbine, the inverter connects to and supplies fixed current, variable voltage, variable frequency, AC power to the permanent magnet turbogenerator/motor, driving the permanent magnet turbogenerator/motor as a motor to accelerate the gas turbine. During this acceleration, spark and fuel are introduced in the correct sequence, and self-sustaining gas turbine operating conditions are reached.

At this point, the inverter is disconnected from the permanent magnet generator/motor, reconfigured to a controlled 60 hertz mode, and then either supplies regulated 60 hertz three phase voltage to a stand alone load or phase locks to the utility, or to other like controllers, to operate as a supplement to the utility. In this mode of operation, the power for the inverter is derived from the permanent magnet generator/motor via high frequency rectifier bridges. The microprocessor monitors turbine conditions and controls fuel flow to the gas turbine combustor.

The energy storage and discharge system includes an ancillary electric storage device, such as a battery, connected to the generator controller through control electronics. Electrical energy can flow from the ancillary electric storage device to the turbogenerator controller during start up and increasing load and vice versa during self-sustained operation of the turbogenerator.

When utility power is unavailable, the ancillary electric storage device can provide the power required to start the turbogenerator. When a load transient occurs, the gas turbine engine and the ancillary electric storage device provide the power required to successfully meet the transient. The output power control regulates a constant AC voltage

and any load placed on the output will immediately require more power to maintain the same level of AC voltage output. As this occurs, the internal DC bus will immediately start to droop and the response to this droop is performed by the ancillary electric storage device controls which draws current out of the device to regulate the DC bus voltage. As turbogenerator system power output increases, the gas turbine engine controls respond by commanding the gas turbine engine to a higher speed. In this configuration, power demand equals power output and once the gas turbine engine output exceeds the system output, the ancillary electric storage device no longer supplies energy but rather starts to draw power from the DC bus to recharge itself.

Please amend the DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS at column 3, lines 34-67, as follows:

A permanent magnet turbogenerator/motor 10 is illustrated in FIG. 1 as an example of a turbogenerator/motor [utilizing the] that may be utilized with a controller [of] in accordance with the present invention. [The] A permanent magnet turbogenerator/motor 10 generally [comprises] includes a permanent magnet generator 12, a power head 13, a combustor 14 and a recuperator (or heat exchanger) 15.

[The] A permanent magnet generator 12 generally includes a permanent magnet rotor or sleeve 16, having a permanent magnet disposed therein, rotatably supported within a stator 18 by a pair of spaced journal bearings. Radial stator cooling fins 25 are enclosed in an outer cylindrical sleeve 27 to form an annular air flow passage which cools the stator 18 and thereby preheats the air passing through on its way to the power head 13.

The power head 13 of the permanent magnet turbogenerator/motor 10 will typically include[s] compressor 30, turbine 31, and bearing rotor 36 through which the tie rod 29 passes. The compressor 30, having compressor impeller or wheel 32 which receives preheated air from the annular air flow

passage in cylindrical sleeve 27 around the stator 18, is driven by the turbine 31 having turbine wheel 33 which receives heated exhaust gases from the combustor 14 supplied with air from recuperator 15. The compressor wheel 32 and turbine wheel 33 [are] may be rotatably supported by bearing shaft or rotor 36 which may have [having] radially extending bearing rotor thrust disk 37. The bearing rotor 36 [is] may be rotatably supported by a single journal bearing within the center bearing housing while the bearing rotor thrust disk 37 at the compressor end of the bearing rotor 36 [is] may be rotatably supported by a bilateral thrust bearing. [The] A bearing rotor thrust disk 37 is usually adjacent to the thrust face at the compressor end of the center bearing housing while a bearing thrust plate is typically disposed on the opposite side of the bearing rotor thrust disk 37 relative to the center housing thrust face.

In the Claims:

Please add new claims 24-48:

24. A method of controlling a turbogenerator having an energy storage device, the method comprising:
rotating the turbogenerator at a first predetermined speed to provide a required amount of power to a load;
in response to a change in the amount of power required by the load, providing power to the load from the energy storage device; and then
rotating the turbogenerator at a second predetermined speed to provide to the load the changed amount of power required.

25. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device to allow the turbogenerator speed to change to the second predetermined speed.

26. The method of claim 25, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

27. The method of claim 25, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

28. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

29. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

30. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device to change the turbogenerator speed to the second predetermined speed.

31. The method of claim 30, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

32. The method of claim 30, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

33. The method of claim 30, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

34. The method of claim 30, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

35. The method of claim 24, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

36. The method of claim 24, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

37. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

38. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

39. A turbogenerator, comprising:

an electric generator electrically connected to a load for providing a required amount of power to the load;

a turbine coupled to the generator for rotating the generator at a first predetermined speed to produce the required amount of power;

an energy storage device electrically connected to the load and to the generator; and

a controller connected to the turbine and to the energy storage device for responding to a change in the amount of power required by providing power to the load from the energy storage device and controlling the turbine speed to a second predetermined speed to provide to the load the changed amount of power required.

40. The turbogenerator of claim 39, wherein the controller comprises:

a controller connected to the energy storage device for responding to a change in the amount of power required by providing power to the load from the energy storage device to

allow the turbogenerator speed to change to the second predetermined speed.

41. The turbogenerator of claim 40, wherein the controller comprises:

a controller connected to the generator for providing power from the turbogenerator to the energy storage device after controlling the turbine speed to the second predetermined speed.

42. The turbogenerator of claim 40, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

43. The turbogenerator of claim 40, the controller comprises:

a controller connected to the generator for providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the generator.

44. The turbogenerator of claim 40, wherein the controller comprises:

a controller connected to the energy storage device for providing power to the load from the energy storage device at a predetermined rate.

45. The turbogenerator of claim 39, wherein the controller comprises:

a controller connected to the generator for providing power from the turbogenerator to the energy storage device

after controlling the turbine speed to the second predetermined speed.

46. The turbogenerator of claim 39, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

47. The turbogenerator of claim 39, the controller comprises:

a controller connected to the generator for providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the generator.

48. The turbogenerator of claim 39, wherein the controller comprises:

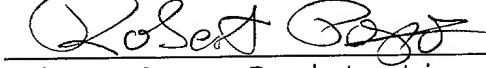
a controller connected to the energy storage device for providing power to the load from the energy storage device at a predetermined rate.

PATENT

Pursuant to 37 C.F.R. 1.121(c)(3), all amendments presented above are shown in clean form on the sheets attached hereto. No new matter has been added by this Amendment and prompt and favorable consideration is respectfully requested.

Respectfully submitted,

December 31, 2001



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SUMMARY OF THE INVENTION

In one aspect of the present invention, a method of controlling a permanent magnet turbogenerator/motor is provided comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a pulse width modulated inverter to start the permanent magnet turbogenerator/motor to achieve self-sustaining operation of the permanent magnet turbogenerator/motor; disconnecting the utility electrical power from the pulse width modulated inverter once self sustaining operation of the permanent magnet turbogenerator/motor is achieved; reconfiguring the pulse width modulated inverter to supply voltage from the permanent magnet turbogenerator/motor; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In another aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self-sustaining operation of the gas turbine engine; disconnecting the utility

electrical power from the pulse width modulated inverter once self-sustaining operation of the gas turbine engine is achieved; reconnecting the pulse width modulated inverter to the permanent magnet turbogenerator/motor through a rectifier bridge to reconfigure the pulse width modulated inverter to supply utility frequency voltage; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In a further aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine, comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a first contactor and a pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor through a second contactor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of the gas turbine engine; opening the first and second contactors to disconnect the utility electrical power from the pulse width modulated inverter once self-sustaining operation of the gas turbine engine is achieved; reconnecting the pulse width modulated inverter to the permanent magnet turbogenerator/motor through a rectifier bridge to reconfigure the pulse width modulated inverter to supply utility frequency voltage; and providing an energy storage

and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the inverter cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In still another aspect, the invention provides a method of controlling a permanent magnet turbogenerator/motor including a gas turbine engine, comprising the steps of providing utility electrical power to the permanent magnet turbogenerator/motor through a first contactor and a multiple solid state switching device channel pulse width modulated inverter to drive the permanent magnet turbogenerator/motor as a motor through a second contactor to accelerate the gas turbine engine of the permanent magnet turbogenerator/motor; providing spark and fuel to the gas turbine engine of the permanent magnet turbogenerator/motor during this acceleration to achieve self-sustaining operation of the gas turbine engine; opening the first and second contactors to disconnect the utility electrical power from the multiple solid state switching device channel pulse width modulated inverter once self sustaining operation of the gas turbine engine is achieved; reconnecting the multiple solid state switching device channel pulse width modulated inverter to the permanent magnet turbogenerator/motor through a high frequency rectifier bridge to reconfigure the multiple solid state switching device channel pulse width modulated inverter; connecting the reconfigured multiple solid state switching device channel pulse width modulated inverter to

utility power by closing a third contactor; and providing an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the gas turbine engine cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In yet another aspect, the invention provides a controller for a permanent magnet turbogenerator/motor including a gas turbine engine comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor; means to provide utility electrical power to said permanent magnet turbogenerator/motor through said pulse width modulated inverter to start said permanent magnet turbogenerator/motor to achieve self sustaining operation of the permanent magnet turbogenerator/motor; means to disconnect the utility electrical power from said pulse width modulated inverter once self sustaining operation of said permanent magnet turbogenerator/motor is achieved; means to reconfigure said pulse width modulated inverter to supply voltage from said permanent magnet turbogenerator/motor; and an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter, when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor, during self-sustained operation when the inverter cannot meet an instantaneous load requirement, after shutdown to continue motoring the gas turbine engine of

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the permanent magnet generator/motor to cool down the permanent magnet generator/motor, and to otherwise store electrical energy during self-sustained operation.

In a further aspect, the invention provides a controller for a permanent magnet turbogenerator/motor having a gas turbine engine comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor; means to provide utility electrical power to said permanent magnet turbogenerator/motor through said pulse width modulated inverter to drive said permanent magnet turbogenerator/motor as a motor to accelerate said gas turbine engine of said permanent magnet turbogenerator/motor; means to provide spark and fuel to said gas turbine engine of said permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of said gas turbine engine; means to disconnect the utility electrical power from said pulse width modulated inverter and said permanent magnet turbogenerator/motor once self-sustaining operation of said gas turbine engine is achieved; a rectifier bridge operably associated with said pulse width modulated inverter and said permanent magnet turbogenerator/motor; means to reconnect said pulse width modulated inverter to said permanent magnet turbogenerator/motor through said rectifier bridge to reconfigure said pulse width modulated inverter to supply utility frequency voltage; and an energy storage and discharge system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the gas turbine engine cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In a still further aspect, the invention provides a controller for a permanent magnet turbogenerator/ motor having a gas turbine engine and a permanent magnet generator/motor comprising a pulse width modulated inverter operably associated with said permanent magnet turbogenerator/motor, said pulse width modulated inverter having a plurality of solid state switching device channels; a first contactor operably associated with said pulse width modulated inverter; a second contactor operable associated with said the permanent magnet turbogenerator/motor; means to provide utility electrical power to said pulse width modulated inverter through said first contactor when closed to drive said permanent magnet turbogenerator/motor as a motor through said second contactor when closed to accelerate said gas turbine engine of said permanent magnet turbogenerator/motor; means to provide spark and fuel to said gas turbine engine of said permanent magnet turbogenerator/motor during this acceleration to achieve self sustaining operation of said gas turbine engine; means to open said first and second contactors to disconnect the utility electrical power from said pulse width modulated inverter once self sustaining operation of said gas turbine engine is achieved; a rectifier bridge operable associated with said pulse width modulated inverter and said permanent magnet turbogenerator/motor; a third contactor operably associated with said pulse width modulated inverter; means to reconnect said pulse width modulated inverter to said permanent magnet turbogenerator/motor through said rectifier bridge to reconfigure said pulse width modulated inverter; means to connect said reconfigured pulse width modulated inverter to supply utility frequency voltage to a load through said third contactor when closed; and an energy storage and discharge

system for the pulse width modulated inverter to provide electrical energy to the inverter when utility electrical power is unavailable to start the permanent magnet turbogenerator/motor and during self-sustained operation when the inverter cannot meet an instantaneous load requirement and to otherwise store electrical energy during self-sustained operation.

In still another aspect, the invention provides a method of controlling a turbogenerator having an energy storage device, the method comprising rotating the turbogenerator at a first predetermined speed to provide a required amount of power to a load; in response to an increase in the amount of power required by the load, providing power to the load from the energy storage device; and then rotating the turbogenerator at a second predetermined speed to provide to the load the increased amount of power required.

PCT/US97/03560

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The turbogenerator/motor controller of the present invention is a microprocessor-based inverter having multiple modes of operation and including an energy storage and discharge system. To start the turbine, the inverter connects to and supplies fixed current, variable voltage, variable frequency, AC power to the permanent magnet turbogenerator/motor, driving the permanent magnet turbogenerator/motor as a motor to accelerate the gas turbine. During this acceleration, spark and fuel are introduced in the correct sequence, and self-sustaining gas turbine operating conditions are reached.

At this point, the inverter is disconnected from the permanent magnet generator/motor, reconfigured to a controlled 60 hertz mode, and then either supplies regulated 60 hertz three phase voltage to a stand alone load or phase locks to the utility, or to other like controllers, to operate as a supplement to the utility. In this mode of operation, the power for the inverter is derived from the permanent magnet generator/motor via high frequency rectifier bridges. The microprocessor monitors turbine conditions and controls fuel flow to the gas turbine combustor.

The energy storage and discharge system includes an ancillary electric storage device, such as a battery, connected to the generator controller through control electronics. Electrical energy can flow from the ancillary electric storage device to the turbogenerator controller during start up and increasing load and vice versa during self-sustained operation of the turbogenerator.

When utility power is unavailable, the ancillary electric storage device can provide the power required to

start the turbogenerator. When a load transient occurs, the gas turbine engine and the ancillary electric storage device provide the power required to successfully meet the transient. The output power control regulates a constant AC voltage and any load placed on the output will immediately require more power to maintain the same level of AC voltage output. As this occurs, the internal DC bus will immediately start to droop and the response to this droop is performed by the ancillary electric storage device controls which draws current out of the device to regulate the DC bus voltage. As turbogenerator system power output increases, the gas turbine engine controls respond by commanding the gas turbine engine to a higher speed. In this configuration, power demand equals power output and once the gas turbine engine output exceeds the system output, the ancillary electric storage device no longer supplies energy but rather starts to draw power from the DC bus to recharge itself.

A permanent magnet turbogenerator/motor 10 is illustrated in FIG. 1 as an example of a turbogenerator/motor that may be utilized with a controller in accordance with the present invention. A permanent magnet turbogenerator/motor 10 generally includes a permanent magnet generator 12, a power head 13, a combustor 14 and a recuperator (or heat exchanger) 15.

A permanent magnet generator 12 generally includes a permanent magnet rotor or sleeve 16, having a permanent magnet disposed therein, rotatably supported within a stator 18 by a pair of spaced journal bearings. Radial stator cooling fins 25 are enclosed in an outer cylindrical sleeve 27 to form an annular air flow passage which cools the stator 18 and thereby preheats the air passing through on its way to the power head 13.

The power head 13 of the permanent magnet turbogenerator/ motor 10 will typically include compressor 30, turbine 31, and bearing rotor 36 through which the tie rod 29 passes. The compressor 30, having compressor impeller or wheel 32 which receives preheated air from the annular air flow passage in cylindrical sleeve 27 around the stator 18, is driven by the turbine 31 having turbine wheel 33 which receives heated exhaust gases from the combustor 14 supplied with air from recuperator 15. The compressor wheel 32 and turbine wheel 33 may be rotatably supported by bearing shaft or rotor 36 which may have radially extending bearing rotor thrust disk 37. The bearing rotor 36 may be rotatably supported by a single journal bearing within the center bearing housing while the bearing rotor thrust disk 37 at the compressor end of the bearing rotor 36 may be rotatably supported by a bilateral thrust bearing. A bearing rotor thrust disk 37 is usually adjacent to the thrust face at the compressor end of the center bearing housing while a bearing thrust plate is typically disposed on the opposite side of the bearing rotor thrust disk 37 relative to the center housing thrust face.

WHAT IS CLAIMED IS:

24. A method of controlling a turbogenerator having an energy storage device, the method comprising:

rotating the turbogenerator at a first predetermined speed to provide a required amount of power to a load;

in response to a change in the amount of power required by the load, providing power to the load from the energy storage device; and then

rotating the turbogenerator at a second predetermined speed to provide to the load the changed amount of power required.

25. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device to allow the turbogenerator speed to change to the second predetermined speed.

26. The method of claim 25, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

27. The method of claim 25, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

28. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

29. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

30. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device to change the turbogenerator speed to the second predetermined speed.

31. The method of claim 30, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

32. The method of claim 30, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

33. The method of claim 30, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

34. The method of claim 30, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

35. The method of claim 24, further comprising after rotating the turbogenerator at the second predetermined speed:

providing power from the turbogenerator to the energy storage device.

36. The method of claim 24, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

37. The method of claim 24, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the turbogenerator.

38. The method of claim 25, wherein providing power from the storage device comprises:

providing power to the load from the energy storage device at a predetermined rate.

39. A turbogenerator, comprising:

an electric generator electrically connected to a load for providing a required amount of power to the load;

a turbine coupled to the generator for rotating the generator at a first predetermined speed to produce the required amount of power;

an energy storage device electrically connected to the load and to the generator; and

a controller connected to the turbine and to the energy storage device for responding to a change in the amount of power required by providing power to the load from the energy storage device and controlling the turbine speed to a second predetermined speed to provide to the load the changed amount of power required.

40. The turbogenerator of claim 39, wherein the controller comprises:

a controller connected to the energy storage device for responding to a change in the amount of power required by providing power to the load from the energy storage device to allow the turbogenerator speed to change to the second predetermined speed.

41. The turbogenerator of claim 40, wherein the controller comprises:

a controller connected to the generator for providing power from the turbogenerator to the energy storage device after controlling the turbine speed to the second predetermined speed.

42. The turbogenerator of claim 40, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

43. The turbogenerator of claim 40, the controller comprises:

a controller connected to the generator for providing power to the load from the energy storage device in response

to a change in the voltage of the power provided by the generator.

44. The turbogenerator of claim 40, wherein the controller comprises:

a controller connected to the energy storage device for providing power to the load from the energy storage device at a predetermined rate.

45. The turbogenerator of claim 39, wherein the controller comprises:

a controller connected to the generator for providing power from the turbogenerator to the energy storage device after controlling the turbine speed to the second predetermined speed.

46. The turbogenerator of claim 39, wherein the energy storage device is selected from the group of energy storage devices comprising batteries, flywheels, and capacitors.

47. The turbogenerator of claim 39, the controller comprises:

a controller connected to the generator for providing power to the load from the energy storage device in response to a change in the voltage of the power provided by the generator.

48. The turbogenerator of claim 39, wherein the controller comprises:

a controller connected to the energy storage device for providing power to the load from the energy storage device at a predetermined rate.